is well known on account of his researches on the Sivalik fossil Mammalia, succeeded to the post. Dr. Thomas Thomson, the co-worker of Sir Joseph Hooker in the collection and distribution of an extensive East Indian Herbarium, was the next Superintendent. His successor, Dr. Thomas Anderson, died in 1870 from disease contracted when labouring to introduce the quinine-yielding Cinchonas into the Himalayas. This latter work—that is, the cultivation of the Cinchonas of the Andes—has been a great success. The Garden authorities, in connection with the Agri-Horticultural Society of India, made great and successful efforts to improve the quality of Indian cotton, and to push its sale and that of jute in the European markets. The united bodies also imported better kinds of sugar-cane from the West Indies, and thus improved the quality and the amount of the sugar-crop in India. The various Superintendents made from time to time experiments in the cultivation of plants and products of economic value, as, for instance, tapioca, india-rubber, sarsaparilla, aloes, cocoa, and many others. Many of the various kinds of exotics now grown in India have been introduced through the instrumentality of the Garden, and the authorities have shown to the inhabitants of India the advantages of better systems of cultivation than they previously pursued.

In the year 1864 the Garden was devastated by a terrible cyclone, and the few plants that escaped the general ruin were very much thinned by another cyclone which a few years after burst over Calcutta. In fact, at the present moment there are in the Garden only a few trees, including the great banyan, which were there in 1867. When the shade of the trees was thus removed, the weed *Imperata cylindrica* spread rapidly over the whole Garden, and when Dr. King was appointed to be Superintendent of the Garden, in 1871, he found it in rather a sorry plight. By the assistance that the local authorities gave him he was enabled to plant it afresh, to lay it out for landscape effect, to form ornamental ponds, and to build the Herbarium and conservatories. The most noticeable feature from a botanical stand-point is, of course, the Herbarium. On Dr. Wallich dispersing in 1828 the splendid collection of dried plants, the foundations of another were laid. Almost every botanical student in India has contributed to the present collection, and also many specimens have been sent from Europe. Of course it is above all an Indian Herbarium, but there are also good collections of plants from Asia Minor, Persia, Japan, and South-Eastern Asia. In fact, in all but African and American plants it is a very representative collection. For the last fifty years there has been a constant exchange of specimens with Kew Gardens, and to Sir William Hooker, and Sir Joseph Hooker, and Mr. Thiselton Dyer, the Herbarium owes some of its choicest specimens. Exchanges have also been systematically made with the British Museum Herbarium, the Jardin des Plantes, Paris, the Imperial Gardens at Berlin and St. Petersburg, and with the institutions at Ceylon, Java, and Saharanpore, and many of the best-known botanists have been among the most active contributors.

During the past year the collection of dried plants has been largely increased, the most noteworthy additions being those collected by Dr. Aitchison with the Afghan Boundary Commission, and those by Dr. Giles during the Gilgit expedition, the latter having been sent from Kew. From Kew were also received many specimens of Singapore and Penang plants. Many plants from Central Asia were sent by the Director of the Imperial Garden at St. Petersburg, and a Natal collection was sent from Durban. Four hundred named species from Mexico, a large box of dried plants from New Guinea, a quantity of plants from Sikkim, trees from the Khasia Hills, specimens from the North-Western Himalayas, and from Southern India, were among the many collections presented to the Garden in the past year. The Government Botanist of Perak, Father Scortechini, who had been sent by Sir H. Low, came to the Garden in November to study, so that he might arrange his collections, but he died shortly after his arrival. During the year 8064 plants were received and 46,109 given out; 903 packets of seeds were received, and 2534 distributed. Dr. King concludes his Report by saying that the acclimatized English potatoes have everywhere turned out badly the past season.

THE BRITISH ASSOCIATION.

SECTION G.

MECHANICAL SCIENCE.

OPENING ADDRESS BY WILLIAM HENRY PREECE, F.R.S., M.INST.C.E., &c., PRESIDENT OF THE SECTION.

"CANST thou send lightnings, that they may go, and say unto thee, Here we are?" were pregnant words addressed to Job unknown centuries ago. They express the first recorded idea in history of the potentiality of electricity to minister to the wants of mankind. From Job to Franklin is a long swing in the pendulum of time. It was not until that American philosopher brought down atmospheric electricity by his kite-string in 1747, and showed that we could lead it where we willed, that we were able to answer the question addressed to the ancient patriarch. Nearly another century elapsed before this mysterious power of Nature was fairly conquered. It has been during this generation, and during the life of the British Association, that electricity has been usefully employed; and it is because I have taken a subordinate position in inaugurating nearly all of its practical applications, that I venture to make the developments of them the text of my address to this Section.

People are singularly callous in matters affecting their own personal safety: they will not believe in mysteries, and they ridicule or condemn that which they do not understand. The Church itself set its face against Franklin's "impious" theories, and he was laughed to scorn by Europe's scientific sons; and even now, though Commissions composed of the ablest men of the land have sat and reported on Franklin's work in England, France, and nearly every civilized nation, the public generally remains not only ignorant of the use of lightning-conductors, but absolutely indifferent to their erection, and, if erected, certainly careless of their proper maintenance. I found in a church not very far from here the conducter leaded into a tombstone, and in a neighbouring cathedral the conductor only a few inches in the ground, so that I could draw it out with my hand. Although I called the attention of the proper authorities to the absolute danger of the state of affairs, they remained in the same condition for years.

Wren's beautiful steeple in Fleet Street, St. Bride's, was well-nigh destroyed by lightning in 1764. A lightning-rod was fixed, but so imperfectly that it was again struck. In July last (1887) it was damaged because the conductor had been neglected, and had lost its efficiency.

As long as points remain points, as long as conductors remain conductors, as long as the rods make proper connection with the earth, lightning protectors will protect: but if points are allowed to be fused, or to corrode away; as long as bad joints or faulty connections are allowed to remain; as long as bad earths, or no earths exist, so long will protectors cease to protect, and they will become absolute sources of danger. Lightning-conductors, if properly erected, duly maintained, and periodically inspected, are an absolute source of safety; but if erected by the village blacksmith, maintained by the economical churchwarden, and never inspected at all, a loud report will some day be heard, and the beautiful steeple will convert the churchyard into a new geological formation.

We have not yet acquired that mental confidence in the accuracy of the laws that guide our procedure in protecting buildings from the effects of atmospheric electrical discharges which characterizes most of the practical applications of electricity. Some of our cherished principles have only very recently received a rough shaking from the lips of Prof. Oliver Lodge, F.R.S., who, however, has supported his brilliant experiments by rather fanciful speculation, and whose revolutionary conclusions are scarcely the logical deduction from his novel premises. The whole subject is going to be thoroughly discussed at this meeting.

We are now obtaining much valuable information about the nature of lightning from photography. We learn that it does not, as a rule, take that zigzag course conventionally used to represent a flash on canvas. Its course is much more erratic and sinuous, its construction more complicated, and pictures have been obtained of *dark* flashes whose *raison d'être* has not yet been satisfactorily accounted for. The network of telegraph wires all over the country is peculiarly subject to the effects of atmospheric electricity, but we have completely mastered the vagaries of lightning discharges in our apparatus and cables. Accidents are now very few and far between.

The art of transmitting intelligence to a distance beyond the reach of the ear and the eye, by the instantaneous effects of electricity, had been the dream of the philosopher for nearly a century, when in 1837 it was rendered a practical success by the commercial and far-sighted energy of Cooke, and the scientific knowledge and inventive genius of Wheatstone. The metallic arc of Galvani (1790) and the developments of Volta (1796) had been so far improved that currents could be generated of any strength; the law of Ohm (1828) had shown how they could be transmitted to any distances; the deflection of the magnetic needle by Oersted in 1819, and the formation of an electro-magnet by Ampère and Sturgeon, and the attraction of its armature, had indicated how those currents could be rendered visible as well as audible.

Cooke and Wheatstone in 1837 utilized the deflection of the needle to the right and the left to form an alphabet. Morse used the attraction of the armature of an electro-magnet to raise a metal style to impress or emboss moving paper with visible dots and dashes. Steinheil imprinted dots in ink on the different sides of a line on paper, and also struck two bells of different sound to affect the ear. Bréguet reproduced in miniature the actual movements of the semaphore, then so much in use in France; while others rendered practical the favourite idea of moving an indicator around a dial, on which the alphabet and the numerals were printed, and causing it to dwell against the symbol to be read—the A, B, C instrument of Wheatstone in England, and of Siemens in Germany. Wheatstone conceived the notion of printing the actual letters of the alphabet in bold Roman type on paper—a plan which was made a perfect success by Hughes in 1854.

At the present moment the needle system of Cooke and Wheatstone, as well as the A, B, C dial telegraph, are very largely used in England on our railways and in our smaller post-offices. The Morse recorder and the Hughes type-printer are universally used on the Continent; while in America the dot-and-dash alphabet of Morse is impressed on the consciousness through the ear by the sound of the moving armature striking against the stops that limit its motion. In our larger and busier offices the Morse sounder and the bell system, as perfected by Bright, are very largely used, while the Press of this country is supplied with news which is recorded on paper by ink dots and dashes at a speed that is almost fabulous.

Sir William Thomson's mirror—the most delicate form of the needle system—where the vibratory motions of an imponderable ray of light convey words to the reader; and his recorder, where the wavy motion of a line of ink spirted on paper by the frictionless repulsion of electricity perform, the same function, are exclusively employed on our long submarine cables.

Bakewell, in 1848, showed how it was possible to reproduce facsimiles of handwriting and of drawing at a distance: and, in 1879, E. A. Cowper reproduced one's own handwriting, the moving pen at one station so controlling the currents flowing on the line wire that they caused a similar pen to make similar motions at the other distant station. Neither of these plans, the former beautifully developed by Caselli and D'Arlincourt, and the latter improved by Robertson and Elisha Gray, have yet reached the practical stage.

The perfection of telegraphy has been attained by that chief marvel of this electrical age—the speaking telephone of Graham Bell. The reproduction of the human voice at a distance, restricted only by geographical limits, seems to have reached the confines of human ingenuity; and though wild enthusiasts have dreamt of reproducing objects abroad visible to the naked eye at home, no one at the present moment can say that such a thing is possible, while in face of the wonders that have been done no one dare say that it is impossible.

The commercial business of telegraphy, when our thoughts and wishes, orders and wants, could be transmitted for money, was inaugurated in this country by the establishment of the Electric Telegraph Company in 1846, and until 1870 it remained in the hands of private enterprise, when it was purchased by the Government, and placed under the sole control of the Postmaster-General. It has been the fashion to decry the terms of purchase of the various undertakings then at work by those who have not understood the question, and by those who, being politically opposed to the Government in power at the time, saw all their acts, not only through a glass darkly, but through a reversing lens. A business producing £550,000 per annum was bought at twenty years' purchase, and that business has now increased to £2,000,000 per annum. 6,000,000 messages per annum have increased to 52,000,000.

Every post-office has been made a telegraph-office, every village of any size has its wire; messages which used to cost 12*s*. 6*d*. are now sent for 6*d*.; a tariff which was vexatious from its unfair variation is now uniform over the United Kingdom, and no one can justly complain of error or delay in the transmission of their messages. Silly complaints are sometimes inserted in the Press, of errors which the most elementary knowledge of the Morse alphabet would detect, and little credit is given to the fact that the most perfect telegraph is subject to strange disturbances from terrestrial and atmospheric causes which admit sources of error beyond the control of the telegraphist. A flash of lightning in America may cause an extra dot in Europe, and *man* may become *war*. An earthquake in Japan may send a dash through France, and *life* would become *wife*. A wild goose flying against a telegraph wire might drive it into momentary contact with another wire, and *sight* might become *night*. Everyone should know his Morse alphabet, and people should learn how to write. Nine-tenths of the errors made are due to the execrable calligraphy of the present day. As a matter of fact, in ninety-nine cases out of a hundred, the telegraphist delivers to the editor of a newspaper "copy" far more accurate than the first proof of his own leader submitted by the printer. The quantity of news transmitted is enormous: an average of 1,538,270 words are delivered per day. The recent Convention in Chicago, when the Republican party of the United States nominated their candidate for the Presidentship, created so much business that every American paper has chronicled this big thing as unique. 500,000 words were sent on one night; but we in England, when Mr. Gladstone introduced his celebrated Home Rule Bill on April 8, 1886, sent from the Central Telegraph Office in London 1,500,000 words.

The growth of business has led to vast improvement in the carrying capacity of the wires. Cooke and Wheatstone required five wires for their first needle instrument to work at the rate of four words per minute. One wire can now convey six messages at ten times the speed. The first Morse apparatus could work at about five words a minute: we now transmit news at the rate of 600 words a minute. In 1875 it was thought wonderful to transmit messages to Ireland at 80 words a minute. When I was recently in Belfast I timed messages coming at the rate of 461 words a minute. Duplex working—that is, two messages travelling on the same wire at the same time in opposite directions, the invention of Gintl, of Vienna—is now the normal mode of working; Edison's quadruplex is common; and the Delany system of multiplex working is gradually being introduced, by which six messages are indiscriminately sent in either direction. The telegraphic system of England has been brought to the highest pitch of perfection. We have neither neglected the inventions of other countries, nor have we been chary of exercising inventive skill ourselves, and we have received our full meed of that reward which is always freely bestowed on a British Government official, neglect and abuse. All parts of the civilized world are now united by submarine cables. The *Times* every morning has despatches from every quarter of the globe, giving the news of the previous day. 110,000 miles of cable have been laid by British ships, and nearly £40,000,000 of British capital have been expended by private enterprise in completing this grand undertaking. A fleet of 37 ships is maintained in various oceans to lay new cables and to repair breaks and faults as they occur—faults that arise, among other causes, from chafing on coral reefs, ships' anchors, the onslaught of insects, and earthquakes. The two cables connecting Australia and Java were recently simultaneously broken by an earthquake.

The politician, unmindful of the works of the engineer, is apt to apply to the credit of his own proceedings the growing prosperity of the world. The engineer, however, feels that steam and electricity in his hands have done more to economize labour, to cheapen life, to increase wealth, to promote international friendship, to alleviate suffering, to ward off war, to encourage peace, than all the legislation and all the verbosity of the politician.

The railways of this country are entirely dependent for the conduct of their traffic on the telegraph, and the security of their passengers is mainly due to the working of the block system. A railway—say between London and Bath—is broken up into certain short sections, and only one train is allowed on one section at one time. The presence, motion, and departure of trains are announced and controlled by electric signals, and the out-door signals are governed by these electric signals. There are few more interesting places to visit than a well-equipped signal-box on one of our main railways. The signalman is able to survey the lines all around and about him by aid of his electric signals; he can talk by telegraph or by telephone to his neighbours and his station-master; he learns of the motion of the trains he is marshalling by the different sounds of electric bells; he controls his out-door signals by the deflection of needles, or the movement of miniature semaphores; he learns the true working of his distant signals by their electrical repetition; machinery governs and locks every motion he makes, so that he cannot make a mistake. The safety of railway travelling is indicated by the fact that, while in the five years ending 1878 thirty-five people were killed annually from causes beyond their own control, in the five years ending 1887 the average has been reduced to sixteen. One person is killed in 35,000,000 journeys made by train. Wherever we are dependent on human agency we are subject to human error, and a serious accident very recently at Hampton Wick has shown how the most perfect machinery may be rendered valueless to protect life when perversity, thoughtlessness, or criminality enter as factors into the case.

At the meeting of the Association in Plymouth in 1877, I was able for the first time in this country to show the telephone at work. Since then its use has advanced with giant strides. There are probably a million instruments at work now throughout the civilized world. Its development has been regularly chronicled at our meetings. As far as the receiving part of the apparatus is concerned, it remains precisely the same as that which I brought over from America in 1877; but the transmitter, ever since the discovery of the microphone by Hughes in 1878, has been entirely remodelled. Edison's carbon transmitter was a great step in advance; but the modern transmitters of Moseley, Berliner, D'Arsonval, De Jongh, leave little to be desired. The disturbances due to induction have been entirely eliminated, and the laws regulating the distance to which speech is possible are so well known, that the specification of the circuit required to connect the Land's End with John o' Groats by telephone is a simple question of calculation. A circuit has been erected between Paris and Marseilles, 600 miles apart, with two copper wires of 6½ gauge, weighing 540 pounds per mile, and conversation is easily maintained between those important cities at the cost of three francs for three minutes. One scarcely knows which fact is the more astounding—the distance at which the human voice can be reproduced, or the ridiculously simple apparatus that performs the reproduction. But more marvellous than either is the extreme sensitiveness of the instrument itself, for the energy contained in one heat unit (gramme-water-degree) would, according to Pellat, maintain a continuous sound for 10,000 years.

The influence which electric currents exert on neighbouring wires extend to enormous distances, and communication between trains, and ships in motion, between armies inside and outside besieged cities, between islands and the main-land, has become possible without the aid of wires at all, by the induction which is exerted through space itself. On the Lehigh Valley Railway, in the United States, such a system of telegraphing without wires is in actual daily use.

The conduct of the telephonic business in England is still in the hands of those who hold the patents, and who maintain a most rigid monopoly. These patents have only a short period to run, and when they expire we may expect to find that England will not occupy the very retired position she holds now as a telephone country. Stockholm has more subscribers than London; there are 15,000 subscribers in and about New York, while the number in London is only 4851.

Electric lighting has become popular, not alone from the beauty of the light itself, but from its great hygienic qualities in maintaining the purity and coolness of the air we breathe. The electric light need not be more brilliant than gas, but it must be more healthy. It need not be cooler than a wax candle, but it must be brighter, steadier, and more pleasant to the eye. In fact, it can be rendered the most perfect artificial illuminant at our disposal, for it can illumine a room without being seen directly by the eye; it can be made absolutely steady and uniform without irritating the retina; it does not poison the air by carbonic acid and carbonic oxide, or dirty the decorations by depositing unconsumed carbon; it does not destroy books or articles of vertu and art by forming water which absorbs sulphur acids; and it does not unnecessarily heat the room.

In our Central Savings Bank in London it has been found, after two years' experience of electric lighting, that the average amount of absences from illness has been diminished by about two days a year for each person on the staff. This is equivalent to a gain to the service of the time of about eight clerks in that department alone. Taking the cost at the "overtime" rate only, this would mean a saving in salaries of about £640 a year. The cost of the installation of the electric light was £3349, and the annual cost of working £700 per annum, say a total annual cost of £1034. The cost of the gas consumed for lighting purposes was about £700 a year, so that on the whole there was a direct saving of something like £266 a year to the Government, besides the material advantage of the better work of the staff resulting from the improved atmospheric conditions under which their work is done.

The production of light by any means implies the consumption of energy, and this can be measured in *watts*, or the rate at which this energy is consumed. A watt is $\frac{1}{746}$ part of a *horse-power*. It is a very convenient and sensible unit of power, and will in time replace the meaningless horse-power.

One candle light maintained by		tallow . . .	absorbs	124 watts.
,,	,,	wax	,,	94 ,,
,,	,,	sperm . . .	,,	86 ,,
,,	,,	mineral oil .	,,	80 ,,
,,	,,	vegetable oil .	,,	57 ,,
,,	,,	coal gas . . .	,,	68 ,,
,,	,,	cannel gas . .	,,	48 ,,
,,	,,	electricity (glow)	,,	3 ,,
,,	,,	electricity (arc)	,,	55 ,,

The relative heat generation of these illuminants may be estimated from these figures.

Though the electric light was discovered by Davy in 1810, it was not until 1844 that it was introduced into our scientific laboratories by Foucault; it was not until 1878 that Jablochkoff and Brush showed how to light up our streets effectually and practically; it was not until 1881 that Edison and Swan showed how our homes could be illuminated softly and perfectly. Unpreparedness for such a revolution produced a perfect panic among gas proprietors; inexperience in the use of powerful electric currents resulted in frequent failure and danger; speculation in financial bubbles transferred much gold from the pockets of the weak to the coffers of the unscrupulous; hasty legislation in 1882 restricted the operations of the cautious and the wise; and the prejudice arising from all these causes has, perhaps fortunately, delayed the general introduction of electricity; but now legislation has been improved, experience has been gained, confidence is being restored, and in this beautiful town of Bath fifty streets are about to be lighted, and we see everywhere around and about us in our English homes the pure glow-lamp replacing filthy gas and stinking oil. The economical distribution of the electric current over large areas is annually receiving a fresh impetus. The expensive systems defined in the Act of Parliament of 1882 have entirely disappeared. Hopkinson in England, and Edison in America, showed how a third wire reduced the weight of copper needed by 66 per cent. Gaulard and Gibbs in 1882 showed how the conversion of alternate currents of high electromotive force to currents of low electromotive force by simple induction coils would enable a mere telegraph wire to convey sufficient electricity to light a distant neighbourhood economically and efficiently. Lane Fox in 1879 showed how the same thing could be done by secondary batteries; and Planté, Faure, Sellon, and Parker have done much to prove how batteries can be made to solve the problem of storage; while King and Edmunds have shown how the distribution by secondary batteries can be done as economically as by secondary generators. The Grosvenor Gallery Company in London have proved the practicability of the secondary generator principle by nightly supplying 24,000 glow-lamps scattered over a very wide area of London. The glow-lamp of Edison, which in 1881 required 5 watts per candle, has been so far improved that it now consumes but 2¼ watts per candle. The dynamo, which in the same year weighed 50,000 pounds, absorbed 150 horse power, and cost £4000 for 1000 lamps, now weighs 14,000 pounds, absorbs 110 horse-power, and costs £500 for the same production of external energy; in other words, its commercial output has been increased nearly six times, while its prime cost has been diminished eight times.

The steam-engine has received equal attention. The economy of the electric light when steam is used depends almost entirely on the consumption of coal. With slow-speed low-pressure engines one kilowatt (1000 watts, 1⅓ horse power) may consume 12 pounds of coal per hour; in high-speed high-pressure triple-expansion engines it need not consume more than 1 pound of coal per hour. Willans and Robinson have actually delivered from a dynamo one kilowatt by the consumption of 2 pounds of coal per hour, or by the condensation of 20 pounds of steam.

There is a great tendency to use small economical direct-acting engines in place of large expensive engines, which waste power in countershafting and belts. Between the energy developed in the furnace in the form of heat, and that distributed in our rooms in the form of light, there have been too many points of waste in the intermediate operations. These have now been eliminated or reduced. Electricity can now be produced by steam at 3*d.* per kilowatt per hour. The kilowatt-hour is the Board of Trade unit as defined by the Act of 1882, for which the consumer of electric energy has to pay. Its production by gas-engines costs 6*d.* per kilowatt-hour, while by primary batteries it costs 3*s.* per kilowatt-hour. The Grosvenor Gallery Company supply currents at 7¼*d.* per kilowatt-hour; a 20 candle-power lamp consuming 3 watts per candle, and burning 1200 hours per annum, expends 82,000 watt-hours or 82 kilowatt-hours, and it costs, at 7¼*d.* per unit, 50*s.* per annum. If the electricity be produced on the premises, as is the case in the Post Office, in the House of Commons, and in many large places, it would cost 20*s.* 6*d.* per annum. I have found from a general average under the same circumstances and for the same light in the General Post Office in London that an electric glow-lamp costs 22*s.* and a gas-lamp 18*s.* per annum. The actual cost of the production of one candle light per annum of 1000 hours is as follows:—

	s.	*d.*
Sperm candles	8	6
Gas (London)	1	3
Oil (petroleum)	0	8
Electricity (glow)...	0	9
Electricity (arc)	0	1½

The greatest development of the electric light has taken place on board ship. Our Admiralty have been foremost in this work. All our warships are gradually receiving their equipment. Our ocean-going passenger ships are also now so illumined, and perhaps it is here that the comfort, security, and true blessedness of the electric light are experienced.

Railway trains are also being rapidly fitted up. The express trains to Brighton have for a long time been so lighted, and now several northern railways, notably the Midland, are following suit. Our rocky coasts and prominent landfalls are also having their lighthouses fitted with brilliant arc lamps, the last being St. Catherine's Point, on the Isle of Wight, where 60,000 candles throw their bright beams over the English Channel, causing many an anxious mariner to proceed on his way rejoicing.

Fontaine showed in Vienna, in 1873, that a dynamo was reversible—that is, if rotated by the energy of a moving machine, it would produce electric currents; or, if rotated by electric currents, it would move machinery. An electric current is one form of energy. If we have at one place the energy of falling water, we can, by means of a turbine and a dynamo, convert a certain portion of the energy of this falling water into an electric current. We transmit this current through proper conductors to any other place we like, and we can again, by means of a motor, convert the energy of the current into mechanical energy to do work by moving machinery, drawing tram-cars, or in any other way. We can in this way transmit and utilize 50 per cent. of the energy of the falling water wherever we like. The waste forces of Nature are thus within our reach. The waterfalls of Wales may be utilized in London; the torrents of the Highlands may work the tramways of Edinburgh; the wasted horse-power of Niagara may light up New York. The falls of Bushmills actually do work the tramway from Portrush to the Giant's Causeway, and those of Bessbrook the line from Newry to Bessbrook.

The practicability of the transmission of energy by currents is assured, and the economy of doing this is a mere matter of calculation. It is a question of the relative cost of the transmission of fuel in bulk, or of the transmission of energy by wire. Coal can be delivered in London for 12*s.* per ton. The mere cost of the up-keep of a wire between Wales and London to deliver the same amount of energy would exceed this sum tenfold. For long distances the transmission of energy is at present out of the question. There can be no doubt, however, that for many purposes within limited areas the transmission of energy by electricity would be very economical and effective. Pumps are worked in the mines of the Forest of Dean, cranes are moved in the works of Easton and Anderson at Erith, lifts are raised in banks in London; water is pumped up from wells to cisterns in the house of Sir Francis Truscott, near East Grinstead; ventilation is effected and temperature lowered in collieries; goods, minerals, and fuel can be transmitted by telpherage.

The transmission of power by electricity is thus within the range of practice. It can be distributed during the day by the same mains which supply currents for light by night. Small industries, such as printing, watch-making, tailoring, boot-making, can be cheaply supplied with power. It is thus brought into direct competition with the distribution of power by steam as in America, or by air-pressure as in Paris, or by high-pressure water as in London; and the relative advantages and economies of each system are simple questions of calculation. When that evil day arrives that our supply of natural fuel ceases, then we may look to electricity to bring to our aid the waste energies of Nature—the heat of the sun, the tidal wave of the ocean, the flowing river, the roaring falls, and the raging storm.

There is a mode of transport which is likely to create a revolution in the method of working tramways. A tramcar carries a set of accumulators which supplies a current to work a motor geared to a pair of wheels of the car. The weight, price, day's work, and life of the accumulator is curiously the same as the weight, price, day's work, and life of horseflesh; but the cost of maintenance, the liability to accident, and the chances of failure are much less. Although very great improvements in batteries have been made, and they are now really practical things, sufficient experience in tramcar working has not yet been obtained to say that we have reached the proper accumulator. Nor have we yet acquired the best motor and mode of gearing; but very active experiments are being carried out in various countries, and nothing can prevent their ultimate success.

The property which the electric current possesses, of doing work upon the chemical constitution of bodies so as to break up certain liquid compounds into their constituent parts, and marshal these disunited molecules in regular order, according to a definite law, upon the surfaces of metals in contact with the liquid where the current enters and exists, has led to immense industries in electro-metallurgy and electro-plating. The extent of this industry may be gathered from the fact that there are 172 electro-platers in Sheffield and 99 in Birmingham. The term electro-metallurgy was originally applied to the electro-deposition of a thin layer of one metal on another; but this is now known as electro-plating.

In 1839, Jacobi in St. Petersburg and Spencer in Liverpool laid the foundations of all we know of these interesting arts. Copper was deposited by them so as to obtain exact reproductions of coins, medals, and engraved plates. The first patents in this country and in France were taken out by Messrs. Elkington, of Birmingham, who still occupy the foremost position in the country.

The fine metals, gold and silver, are deposited in thin layers on coarser metals, such as German silver, in immense quantities. Christofle, of Paris, deposits annually six tons of silver upon articles of use and of art, and if the surfaces so electro-plated were spread out continuously they would cover 140 acres.

The whole of the copper plates used in Southampton for the production of our splendid Ordnance Survey maps are deposited by copper on matrices taken from the original engraved plates, which are thus never injured or worn, are always ready for addition or correction, while the copies may be multiplied at pleasure and renewed at will.

Nickel-plating, by which the readily oxidizable metals like iron are coated with a thin layer of the more durable material nickel, is becoming a great industry; the trappings of harness, the exposed parts of machinery, the fittings of cycles and carriages, and innumerable articles of daily use, are being rendered not only more durable but more beautiful.

The electro-deposition of iron, as devised by Jacobi and Klein, in the hands of Prof. Roberts-Austen, F.R.S., is giving very interesting results. The dies for the coins which were struck at our Mint on the occasion of the Jubilee of the Queen were modelled in plaster, reproduced in intaglio by the electro-deposition of copper, and on these copper moulds hard excellent iron in layers of nearly $\frac{1}{10}$ of an inch was deposited.

The exact processes of measurement, which have led to such vast improvement in our telegraphic systems, have scarcely yet penetrated into this field of electrical industry, and little is known at present of the exact relations of current and electromotive force with respect to surfaces of contact, rate of deposit, and resistance of liquids. Captain Sankey, R.E., of the Ordnance Survey Department, has done some useful work in this direction.

The extraction of metals from their ores by deposition has received wide application in the case of copper. In 1871, Elkington proposed to precipitate copper electrolytically from the fused sulphide of copper and iron known to the copper smelter as "regulus." Thin copper plates were arranged to receive the deposited copper, while the foreign metals, including gold and silver, fell to the bottom of the solution, the process being specially applicable, it was supposed, to regulus containing small quantities of the precious metals.

The electrical purification of copper from impure "blister copper" or "blade copper" has also made great progress, and special dynamos are now made which will, with an expenditure of 100 horse-power, precipitate 18 tons of copper per week. The impure metal is made to form the anode in a bath of sulphate of copper, the metal being deposited in the pure form on a thin copper cathode.

It was not very long ago considered very economical to absorb 0·85 horse-power in depositing 1 pound of copper per hour, but now the same work can be done with 0·3 horse-power. Mr. Parker, of Wolverhampton, has done good work in this direction, and his dynamos in Messrs. Bolton's works have revolutionized this process of purification.

Both at Swansea and Widnes, immense quantities of copper, in spite of the restrictive operations of the Copper Syndicate, are being produced by electro-deposition. Copper steam-pipes for boilers are now being built up of great firmness, fine texture, and considerable strength, by Mr. Elmore, at Cockermouth, by electro-deposition on a rotating mandril in a tank of sulphate of copper. By this process one ton of copper requires only a little more than one ton of coal to raise the requisite steam to complete the operation.

It has been shown that the electrolytic separation of silver from gold by similar methods is perfectly practicable. The value of the material to be dealt with may be gathered from the fact, communicated to the Gold and Silver Commission now sitting, that nearly 90,000,000 ounces of silver are annually produced, and the greater portion of this amount contains sufficient gold to render refining remunerative. Although the old acid process of "parting" gold and silver remains practically undisturbed, there seems no reason to doubt that in the future electricity will render us good service in this direction, as it has already in the purification of copper.

There is not much actual progress to report in the extraction of gold from its ores by electrical agency. The conversion of gold into chloride of gold by the direct, or indirect, action of chlorine is employed on a very large scale in [Grass Valley] California and elsewhere. This fact has led to well-directed efforts to obtain, by electrolytic action, chlorine which should attack finely-divided gold suspended (with the crushed ore) in the solution from which the chlorine was generated, the gold, so converted into soluble chloride, then being deposited on a cathode. The process would seem to be hopeful, but is not as yet a serious rival to the ordinary chlorination method.

In the amalgamation of gold ores much is expected from the possibility of keeping clean, by the aid of hydrogen set free by the electric current, the surfaces of amalgamated plates.

It is well known that the late Sir W. Siemens considered that the electric arc might render good service in the fusion of metals with high melting-points, and he actually succeeded in melting 96 ounces of platinum in ten minutes with his electrical furnace. The experiments were interrupted by his untimely death; but in the hands of Messrs. Cowles the electric arc produced by 5000 amperes and 500 horse-power is being employed on a very large scale for the isolation of aluminium (from corundum), which is immediately alloyed (*in situ*) with copper or iron, in the presence of which it is separated.

The heating power of large currents has been used by Elihu Thomson in the United States, and by Bernardos in Russia, to weld metals, and it is said to weld steel without affecting its hardness. It has even been proposed to weld together in one continuous metallic mass the rails of our railways, so as to dispense entirely with joints.

The production of chlorine for bleaching and of iodine for pharmaceutical purposes, the economical production of oxygen, are also processes now dependent on the electrolytic effect of the electric current.

It is almost impossible to enumerate the various general purposes to which electricity is applied to minister to our wants and to add to our comforts. Everyone appreciates the silent efficiency of the trembling electric bell, while all will sooner or later derive comfort from the perennially self-winding electric clock. Correct mean time is distributed throughout the length and breadth of the land by currents derived from Greenwich Observatory. Warehouses and shops are fitted with automatic contact pieces, which, on any undue increase of temperature due to fire, create an alarm in the nearest fire-station; and at the corner of most streets a post is found with a face of glass, which on being broken enables the passer-by or the watchful and active policeman to call a fire-engine to the exact spot of danger. Our sewers are likely to find in its active chemical agency a power to neutralize offensive gases, and to purify poisonous and dangerous fluids. The germs of diseases are attacked and destroyed in their very lairs. The physician and the surgeon trust to it to alleviate pain, to cure disease, to effect organic changes beyond the reach of drugs. The photographer finds in the brilliant rays of the arc lamp a miniature sun which enables him to pursue his lucrative business at night, or during the dark and dismal hours of a black November fog in London.

We learn from the instructive and interesting advertising columns of our newspaper that "electricity is life," and we may perhaps read in the more historical portion of the same paper that by a recent decision of the New York Parliament, "electricity is death." It is proposed to replace hanging by the more painless and sudden application of a powerful electrical charge; but those who have assisted at this hasty legislation would have done well to have assured themselves of the practical efficacy of the proposed process. I have seen the difficulty of killing even a rabbit with the most powerful induction coil ever made, and I know those who escaped and recovered from the stroke of a lightning discharge.

The fact that the energy of a current of electricity, either when it flashes across an air space, or when it is forced through high resistance, assumes the form of heat of very high temperature led early to its employment for firing charges of gunpowder; and for many civil, military, and naval purposes it has become an invaluable and essential agent. Wrecks like that of the *Royal George* at Spithead were blown up and destroyed; the faces of cliffs and quarries are thrown down; the galleries of mines and tunnels are excavated; obstructions to navigation like the famous Hell Gate, near New York, have been removed; time-guns to distribute correct time are fired by currents from Greenwich at 1 p.m. In the operations of war, both for attack and defence, submarine mining has become the most important branch of the profession of a soldier and a sailor. Big guns, whether singly or in broadside, are fired; and torpedoes, when an enemy's ship unwittingly is placed over them, are exploded by currents of electricity.

An immense amount of research has been devoted to design the best form of fuse, and the best form of generator of electricity to use to explode them. Gun tubes for firing consist of a short piece of very fine wire embedded in some easily fusible compound, while the best form of fuse is that known as the Abel fuse, which is composed of a small, compact mass of copper phosphide, copper sulphide, and potassium chlorate. The practice in the use of generators is very various. Some, like the Austrians, lean to the high-tension effects of static electricity; others prefer magneto-machines; others use the dynamo; while we in England cling with much fondness to the trustworthy battery. Since the electric light has also become such a valuable adjunct to war purposes, it is probable that secondary batteries will become of immense service. The strong inductive effects of atmospheric electricity are a source of great danger. Many accidental explosions of fuses have occurred. An experimental cable with a fuse at one end was laid below low-water mark along the bank of the Thames at Woolwich. The fuse was exploded during a heavy thunderstorm. The knowledge of the causes of a danger is a sure means for the production of its removal, or of its reduction to a minimum. Low-tension fuses and metallic circuits reduce the evils of lightning, but have not removed them. Should war unhappily break out again in Europe, submarine mining will play a very serious part; and, paradoxical as it may appear—as has been suggested by the French Ambassador, M. Waddington—its very destructiveness may ultimately prove it to be a powerful element of peace.

It seems incredible that, having utilized this great power of Nature to such a wide and general extent, we should be still in a state of mental fog as to the answer to be given to the simple question—What is Electricity? The engineer and the physicist are completely at variance on this point. The engineer regards electricity, like heat, light, and sound, as a definite form of energy, something that he can generate and destroy, something that he can play with and utilize, something that he can measure and apply. The physicist—at least some physicists, for it is difficult to find any two physicists that completely agree with each other—regard electricity as a peculiar form of matter permeating all space as well as all substances, together with the luminiferous ether, which it permeates like a jelly or a sponge. Conductors, according to this theory, are holes or pipes in this jelly, and electrical generators are pumps that transfer this hypothetical matter from one place to another. Other physicists, following Edlund, regard the ether and electricity as identical; and some, the disciples of Helmholtz, consider it as an integral constituent of Nature, each molecule of matter having its own definite charge, which determines its attraction and its repulsion. All attempts to revive the Franklinian, or material, theory of electricity, have, however, to be so loaded with assumptions, and so weighted with contradictions, that they completely fail to remove electricity from the region of the mysterious. It is already extremely difficult to conceive the existence of the ether itself as an infinitely thin, highly elastic medium, filling all space, employed only as the vehicle of those undulatory motions that give us light and radiant heat. The material theory of electricity requires us to add to this another incomprehensible medium embedded or entangled in this ether, which is not only a medium for motion, but which is itself moved. The practical man, with his eye and his mind trained by the stern realities of daily experience, on a scale vast compared with that of the little world of the laboratory, revolts from such wild hypotheses, such unnecessary and inconceivable conceptions, such a travesty of the beautiful simplicity of Nature.

He has a clear conception of electricity as something which has a distinct objective existence, which he can manufacture and sell, and something which the unphilosophic and ordinary member of society can buy and use. The physicist asserts dogmatically: "Electricity may possibly be a form of matter—it is not a form of energy." The engineer says distinctly: "Electricity is a form of energy—it is not a form of matter; it obeys the two great developments of the present generation—the mechanical theory of heat and the doctrine of the conservation of energy." There must be some cause for this strange difference of views. It is clear that the physicist and the engineer do not apply the term electricity to the same thing. The engineer's electricity is a real form of energy; the speculative philosopher's electricity is a vague subjective unreality which is only a mere factor of energy and is not energy itself. This factor, like force, gravity, life, must, at any rate for the present, remain unknowable. It is not known what force is; neither do we know what is matter or gravity. The metaphysician is even doubtful as regards time and space. Our knowledge of these things commences with a definition. The human mind is so unimpressionable, or language is so poor, that writers often cannot agree even on a definition. The definition of energy is capacity for doing work. We practical men are quite content to start from this fiducial line, and to affirm that our electricity is a something which has a capacity for doing work; it is a peculiar form of energy. The physicist may speculate as much as he pleases on the other side of this line. He may take the factors of energy, and mentally play with them to his heart's content; but he must not rob the engineer of his term *electricity*. It is a pity that we cannot settle our difference by changing the term. Physicists might leave the term *electricity* to the form of energy, which is an objective reality, and which the ordinary mortal understands; while engineers would be quite content if speculative physicists and enthusiastic mathematicians would call their subjective unreality, their imaginary electrical matter, by some other term. If it be necessary to mentally create some imaginary matter to fulfil the assumptions and abstractions of their mathematical realizations, let them call it *coulombism* or *electron*, and not appropriate the engineer's generic and comprehensive term electricity. The engineer finds the motions of existing matter and of the ether quite sufficient to meet all his requirements, and to account for all those phenomena which are called electrical.

It seems paradoxical to assert that two unrealities can form a reality, or that two subjective ideas can become an objective one; but it must be remembered that in all electrical phenomena that which makes them real and objective is derived from without. The motion that renders an electrical phenomenon evident is imparted to it from some other form of energy. The doctrine of the conservation of energy asserts that energy is never destroyed, it is only transformed—work must be done to render it evident. No single electrical effect can be adduced which is not the result of work done, and is not the equivalent of energy absorbed. The engineer's notion of work—something done against resistance; and of power—the rate at which this change of condition is effected—are the key-stones to the conception of the character of those great sources of power in Nature whose direction to the uses and convenience of man is the immediate profession of those who generally assemble together in Section G of the British Association to discuss the "practical application of the most important principles of natural philosophy, which has, in a considerable degree, realized the anticipations of Bacon and changed the aspect and state of affairs in the whole world."

I cannot pretend to have given a survey of all the practical applications of electricity. I have but briefly indicated the present area covered by the new and rapidly-growing industry. Five million people upon the globe are now dependent on the electric current for their daily bread. Scarcely a week passes without some fresh practical application of its principles, and we seem to be only on the shore of that sea of economy and beneficence which expands with every new discovery of the properties of electricity, and spreads already beyond the mental grasp of any one single worker.

NOTES.

THE Geological Congress held its first meeting on Tuesday. This week we print the President's address and one of the papers referring to one of the most important points to be considered by the Congress—that of the Crystalline Schists.

INTELLIGENCE has been received of the murder of Major Barttelot, Mr. Stanley's principal lieutenant, by some of his followers when on the way from Stanley Falls with reinforcements for his chief.

THE sudden death of Mr. R. A. Proctor was announced from New York about a week ago. In addition to his writings on various subjects for which his name is so widely known, he made some contributions to the science of astronomy. Some of his books, such as "Saturn and its System," his various star atlases, and others we might name, have a permanent value. Elected a Fellow of the Royal Astronomical Society in 1866, he was for a considerable number of years the most prolific contributor to the *Monthly Notices*. In 1871 he was elected to the Council, and in the following year was appointed the Secretary. The determination of the rotation-period of Mars, a chart of Mars from the collation of a large number of drawings, a long series of papers on transits of Venus, especially the transits of 1874 and 1882, and a yet more important series on the distribution of stars and nebulæ, were communicated to the Astronomical Society during these years. It was in connection with this last series that his greatest single work for science was carried out, viz. the copying of the 324,198 stars of Argelander's "Survey of the Northern Heavens," on an "equal surface" projection chart, a work that involved 400 hours of the most unremitting labour. Mr. Proctor was born at Chelsea, in March 1834, and was educated at King's College, London, of which he was Honorary Fellow, and at St. John's College, Cambridge, where he won a Scholarship. He obtained his degree of B.A. in 1860, and his name appears as twenty-third in the Wrangler's List.